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P 3098200

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CLAIMS

(57) [Claim(s)]

[Claim 1] As opposed to a laser beam to which outgoing radiation of the luminescence side was carried out from a source of laser luminescence which has a longitudinal direction and the direction of a short hand After collimating the 2nd direction component of a beam which met in the direction of a short hand of a luminescence side almost in parallel While making the inside of each light guide plate transmit where it carried out incidence to an optical-path division element which installed two or more light guide plates in the 1st direction which met a longitudinal direction of a luminescence side in this beam and the 1st direction component of a beam is divided While outgoing radiation is carried out from each light guide plate where displacement of each division beam is carried out by predetermined width of face in the 2nd direction, and carrying out incidence of each of this division beam to an optical-path modification element which installed two or more light guide plates in the 2nd direction An amendment method of a laser beam characterized by condensing each division beam which was made to carry out and change outgoing radiation into the condition of having made an optical path of the 1st direction component changing within each light guide plate, and having piled up each division beam in the outgoing radiation side edge section, and carried out outgoing radiation from this optical-path modification element.

[Claim 2] Said optical-path modification element and an optical-path modification element are the amendment method of a laser beam indicated to claim 1 which acquired said optical path of each division beam by setup [which / of whenever / in each light guide plate / incident angle /, an outgoing radiation angle, an outgoing radiation location, or a refractive index].

[Claim 3] A compensator of a laser beam by which it was characterized characterized by providing the following A collimation element for which a luminescence side collimates the 2nd direction component which met in the direction of a short hand of a luminescence side to a laser beam by which outgoing radiation is carried out from a source of laser luminescence which has a longitudinal direction and the direction of a short hand almost in parallel An optical-path division element which installed two or more light guide plates in the 1st direction that outgoing radiation of each division beam should be carried out where displacement is carried out by predetermined width of face in the 2nd direction while making the inside of each light guide plate transmit where the 1st direction component in alignment with a longitudinal direction of a luminescence side is divided An optical-path modification element which installed two or more light guide plates in the 2nd direction that outgoing radiation should be carried out and carried out to the condition of having made an optical path of the 1st direction component of each division beam changing, and having piled up in the outgoing radiation side edge section A condensing element which condenses each division beam which carried out outgoing radiation from an optical-path modification element

[Claim 4] Said optical-path division element and an optical-path modification element are the compensator of a laser beam indicated to claim 3 which consisted of each light guide plate which made parallel an incidence side edge side and an outgoing radiation side edge side of a beam, and formed each light guide plate with a glass plate or an optical-crystal board.

[Claim 5] One of elements is the compensators of a laser beam indicated to claim 4 of said optical-path division element and an optical-path modification element which was made to carry out displacement at a predetermined angle so that whenever [incident angle] may differ from an outgoing radiation angle one by one at least, and installed each light guide plate.

[Claim 6] It is the compensator of a laser beam indicated to claim 5 which each light guide plate of an optical-path modification element could shift an angle on a field which is parallel to the 1st direction, respectively on a field where said optical-path division element and an optical-path modification element consist of each light guide plate of isomorphism which carried out the shape of a rectangle containing a parallelogram, and each light guide plate of an optical-path division element is parallel to the 2nd direction, and was arranged in the shape of a sector.

[Claim 7] It is the compensator of a laser beam indicated to claim 4 which installed each light guide plate of said optical-path division element and an optical-path modification element into which length was changed so that one of elements at least might have whenever [incident angle], and a fixed outgoing radiation angle and outgoing radiation locations of a beam might differ one by one.

[Claim 8] In a field top where said optical-path division element and an optical-path modification element consist of each light guide plate of the shape of a rectangle containing ***** and each light guide plate of an optical-path division element is parallel to the 2nd direction It is the compensator of a laser beam indicated to claim 7 arranged in the condition of having made an incidence side and an outgoing radiation side edge side inclining toward an outgoing radiation side at a predetermined angle on a field where each light guide plate of an optical-path

modification element is parallel to the 1st direction while arranging an incidence side and an outgoing radiation side edge side in the condition of having made a predetermined angle inclining toward an incidence side.

[Claim 9] It is the compensator of a laser beam indicated to claim 4 which installed each light guide plate of said optical-path division element and an optical-path modification element into which a refractive index was changed so that one of elements at least might have whenever [incident angle], and a fixed outgoing radiation angle and refractive indexes of a beam might differ one by one.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[The technical field to which invention belongs] Especially this invention can use an un-round shape [like the laser beam which made it generate from semiconductor laser] shape [of an ellipse which spread in one side] laser beam about the amendment method of a laser beam and equipment which are amended so that it can condense to the minor diameter circle configuration beam spot with an easy and cheap means in science study research, micro laser processing, platemaking, medicine, and other various fields as the light source for excitation of semiconductor laser excitation solid state laser etc.

[0002]

[Description of the Prior Art] Except for a special use, generally, this kind of laser beam is easy to condense, and it needs to use it as the beam of high density. When it is desirable for the beam spot to be a minor diameter if possible in a circle configuration for that purpose, for example, it excites solid state laser by making the laser beam of high power semiconductor laser into excitation light If it is made to condense by the beam spot equal to the oscillation light of solid state laser whose laser beam which carries out incidence from the medium end face of solid state laser is high density It is optical high conversion efficiency, and generally it is known that a good oscillation output beam will be obtained, and it is desirable to make a laser beam condense for that purpose by the beam spot which carried out the circle configuration of hundreds of micrometers in the inside of laser data medium.

[0003] However, the luminescence side of the semiconductor laser called the laser diode bar which made many light emitting devices juxtaposition, for example To one side by long (at the semiconductor laser of 10 – 20W output, luminescence length is 10mm) one with short (for example, luminescence length is 1 micrometer) ** and another side Although the direction component of a short hand can be easily condensed in the small diameter of PIMU (dozens of micrometers or less) when the beam spot of the laser beam by which outgoing radiation is carried out from a luminescence side becomes ellipse-like and it makes the desired beam spot condense this laser beam By the usual optical condensing method which combined the cylindrical lens, the spherical lens, the aspheric lens, etc. to the longitudinal direction component, it is very difficult to extract small and it will become the diameter of PIMU which is about 3mm.

[0004] In addition, although the following explanation explains the case where a longitudinal direction is used in the leveled condition, i.e., the condition that the 2nd direction where the 1st direction in alignment with the longitudinal direction of a luminescence side met in the direction of a short hand in the horizontal plane considered as the vertical plane, so that the luminescence side of said semiconductor laser may become oblong For example, horizontal luminescence length is unable to condense a 10mm beam below to 1mmphi from the aforementioned reason. Therefore, if about [that it is hard to acquire optical high conversion efficiency] and the beam spot becomes ellipse-like when it uses for semiconductor laser excitation solid state laser, an oscillation output beam will also become ellipse-like and the laser beam of high quality will not be obtained.

[0005] As one of the means to solve said technical problem, there is the end-face excitation method using the optical-fiber bunch currently indicated by JP,5-93828,A etc. By this method, output radiation of semiconductor laser for the collimation element made parallel With the collimate lens which combined the optical-fiber bunch of a large number (the light emitting device and the same number of semiconductor laser) to which the end side was horizontally installed in the state of separation, and the other end side banded together in the circle configuration, and was made to approach the luminescence side of said semiconductor laser If outgoing radiation is carried out from the other end side which was made to carry out incidence and banded together from the end side of the optical-fiber bunch which installed this outgoing radiation light after condensing perpendicularly first and collimating in parallel the outgoing radiation light from each light emitting device which constitutes a diode bar As for a laser beam, the small beam spot of a path is obtained in the circle configuration by which the beam of a horizontal direction and a perpendicular direction was equalized.

[0006] In condensing by said end-face excitation method, if it is used for diameter 10mm(15 degrees of angles of divergence) x1micrometer (50 degrees of angles of divergence) semiconductor laser combining an optical-fiber bunch, for example If outgoing radiation of the laser beam is carried out from the field of the diameter of 600 micrometer by 23 degree [of angles of divergence] = (numerical aperture NA=0.2), for example, this laser beam is made to condense with the aspheric lens of numerical aperture NA=0.2 It can be made a beam with a circle configuration of about 600 micrometers, and condensing nature is remarkably improved compared with the horizontal beam diameter of about 6mm at the time of condensing only with the lens of numerical aperture NA=0.2 without

using an optical-fiber bunch.

[0007] If two semiconductor laser (wavelength of 808nm) of output 20W is made into the excitation light source and the solid state laser using laser data-medium Nd:YVO4 with an oscillation wavelength of 1064nm is incidentally irradiated through the condensing means by said end-face excitation method, about 50% of value is acquired as optical conversion efficiency from excitation light to oscillation light.

[0008] Moreover, although the side excitation method which is made to ***** outgoing radiation light of semiconductor laser from the side of the laser medium which carried out the rod configuration, and excites it is also used so that perpendicular chisel condensing may be carried out as other means to improve the condensing nature of semiconductor laser, without making it condense horizontally Since a laser beam is absorbed also in portions other than the field of laser oscillation light by this method, compared with the end-face excitation method using said optical-fiber bunch, optical conversion efficiency length is low and, generally can expect only about 20% of optical conversion efficiency.

[0009]

[Problem(s) to be Solved by the Invention] Since the beam spot can be made into the circle configuration of a minor diameter according to the side excitation method using the former, i.e., the optical-fiber bunch, in a Prior art Although there is an advantage which can raise the optical conversion efficiency from excitation light to oscillation light when this laser beam is used for example, for the excitation light source for solid state laser If much costs and time amount are needed for manufacture of an optical-fiber bunch, for example, manufacture cost is compared about the semiconductor laser excitation light source of 20W class, manufacture cost will soar twice [about] by using said optical-fiber bunch.

[0010]

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TECHNICAL FIELD

[A technical field to which invention belongs] Especially this invention can use an un-round shape [like a laser beam which made it generate from semiconductor laser] shape [of an ellipse which spread in one side] laser beam about an amendment method of a laser beam and equipment which are amended so that it can condense to the minor diameter circle configuration beam spot with an easy and cheap means in science study research, micro laser processing, platemaking, medicine, and other various fields as the light source for excitation of semiconductor laser excitation solid state laser etc.

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 PRIOR ART

[Description of the Prior Art] Except for a special use, generally, this kind of laser beam is easy to condense, and it needs to use it as the beam of high density. When it is desirable for the beam spot to be a minor diameter if possible in a circle configuration for that purpose, for example, it excites solid state laser by making the laser beam of high power semiconductor laser into excitation light. The laser beam which carries out incidence from the medium end face of solid state laser is high density, and if it is made to condense by the beam spot equal to the oscillation light of solid state laser, it is optical high conversion efficiency, and, generally it is known that a good oscillation output beam will be obtained. It is desirable to make a laser beam condense for that purpose by the beam spot which carried out the circle configuration of hundreds of micrometers in the inside of laser data medium.

[0003] However, the luminescence side of the semiconductor laser called the laser diode bar which made many light emitting devices juxtaposition, for example, To one side by long (at the semiconductor laser of 10 – 20W output, luminescence length is 10mm) one with short (for example, luminescence length is 1 micrometer) ** and another side. Although the direction component of a short hand can be easily condensed in the small diameter of PIMU (dozens of micrometers or less) when the beam spot of the laser beam by which outgoing radiation is carried out from a luminescence side becomes ellipse-like and it makes the desired beam spot condense this laser beam. By the usual optical condensing method which combined the cylindrical lens, the spherical lens, the aspheric lens, etc. to the longitudinal direction component, it is very difficult to extract small and it will become the diameter of PIMU which is about 3mm.

[0004] In addition, although the following explanation explains the case where a longitudinal direction is used in the leveled condition, i.e., the condition that the 2nd direction where the 1st direction in alignment with the longitudinal direction of a luminescence side met in the direction of a short hand in the horizontal plane considered as the vertical plane, so that the luminescence side of said semiconductor laser may become oblong, from the aforementioned reason, horizontal luminescence length is unable to condense a 10mm beam below to 1mmphi, for example, therefore it is boiled. If about [that it is hard to acquire optical high conversion efficiency] and the beam spot becomes ellipse-like when it uses for semiconductor laser excitation solid state laser, an oscillation output beam will also become ellipse-like and the laser beam of high quality will not be obtained.

[0005] As one of the means to solve said technical problem, there is the end-face excitation method using the optical-fiber bunch currently indicated by JP,5-93828,A etc. By this method, output radiation of semiconductor laser for the collimation element made parallel. The collimate lens which combined the optical-fiber bunch of a large number (the light emitting device and the same number of semiconductor laser) to which the end side was horizontally installed in the state of separation, and the other end side banded together in the circle configuration, and was made to approach the luminescence side of said semiconductor laser. If outgoing radiation is carried out from the other end side which was made to carry out incidence and banded together from the end side of the optical-fiber bunch which installed this outgoing radiation light after condensing perpendicularly first and collimating in parallel the outgoing radiation light from each light emitting device which constitutes a diode bar, as for a laser beam, the small beam spot of a path will be obtained in the circle configuration by which the beam of a horizontal direction and a perpendicular direction was equalized.

[0006] If it is used for diameter 10mm(15 degrees of angles of divergence) x1micrometer (50 degrees of angles of divergence) semiconductor laser in condensing by said end-face excitation method combining an optical-fiber bunch, for example, If outgoing radiation of the laser beam is carried out from the field of the diameter of 600 micrometer by 23 degree [of angles of divergence] = (numerical aperture NA=0.2), for example, this laser beam is made to condense with the aspheric lens of numerical aperture NA=0.2, it can be made a beam with a circle configuration of about 600 micrometers, and condensing nature will be remarkably improved compared with the horizontal beam diameter of about 6mm at the time of condensing only with the lens of numerical aperture NA=0.2 without using an optical-fiber bunch.

[0007] If two semiconductor laser (wavelength of 808nm) of output 20W is made into the excitation light source and the solid state laser using laser data-medium Nd:YVO4 with an oscillation wavelength of 1064nm is incidentally irradiated through the condensing means by said end-face excitation method, about 50% of value is acquired as optical conversion efficiency from excitation light to oscillation light.

[0008] Moreover, horizontally, perpendicular chisel condensing is carried out as other means to improve the condensing nature of semiconductor laser, without making it condense, Although the side excitation method which is made to ***** outgoing radiation light of semiconductor laser from the side of the laser medium which carried out the rod configuration, and excites it is also used, since a laser beam is absorbed also in portions other than the field

of laser oscillation light by this method, compared with the end face excitation method using said optical fiber bunch, optical conversion efficiency length is low and, generally can expect only about 20% of optical conversion efficiency.

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EFFECT OF THE INVENTION

[Effect of the Invention] With the amendment method and equipment of a laser beam according to this invention so that clearly [the above explanation] While narrowing beam width by condensing after changing into the condition of having once divided the longitudinal direction component of a laser beam, using the optical-path division element and optical-path modification element which installed two or more light guide plates, if attached to the direction component of a short hand of a laser beam with beam width narrow from the first, it is making some breadth permit, and can perform easily making it the beam spot of the small circle configuration of a path. Therefore, if this invention is applied to the semiconductor laser excitation light source for solid state laser, exciting with optical high conversion efficiency will be possible, and the oscillation output beam of high quality will be obtained.

[0059] Moreover, an expensive means is not needed for the achievement like the conventional technology which used the optical-fiber bunch, but it can provide cheaply by setting each light guide plate as an array or a configuration, predetermined length, or a predetermined refractive index, and installing it using the optical crystal which processed a glass plate or tabular into the light guide plate which constitutes an optical-path division element and an optical-path modification element.

[0060] If the light guide plate of an optical-path division element and an optical-path modification element is especially constituted like the 1st operation gestalt, and only the array which carries out a laminating is set as a request, it is isomorphous, and since the thing of this quality of the material can be mass-produced and used, providing cheaply is possible.

[0061] Moreover, if the light guide plate of an optical-path division element and an optical-path modification element is constituted like the 2nd operation gestalt, since the thing of this quality of the material can be mass-produced and it can be cut and used for the desired length, providing cheaply is possible.

[0062] Furthermore, it is possible for assembly cost to become cheap although material cost becomes expensive somewhat compared with before 2 person, since it can be used carrying out the laminating of the thing of isomorphism as it is if the light guide plate of an optical-path division element and optical-path modification element is constituted like the operation gestalt of ** a 3rd and only a refractive index will be set as a request, and to provide cheaply as the whole.

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TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] Since the beam spot can be made into the circle configuration of a minor diameter according to the side excitation method using the former, i.e., the optical-fiber bunch, in a Prior art Although there is an advantage which can raise the optical conversion efficiency from excitation light to oscillation light when this laser beam is used for example, for the excitation light source for solid state laser If much costs and time amount are needed for manufacture of an optical-fiber bunch, for example, manufacture cost is compared about the semiconductor laser excitation light source of 20W class, manufacture cost will soar twice [about] by using said optical-fiber bunch.

[0010] Moreover, according to the side excitation method of not performing, the latter, i.e., horizontal condensing, in a Prior art, there is an advantage which manufacture cost can be cheap and can carry out simple, but the loss by said absorption cannot expect optical conversion efficiency and high.

[0011] so, in this invention, like the laser beam by which outgoing radiation was carried out, for example from semiconductor laser Perform optical amendment to an un-round shape laser beam, and the small beam spot of the path which carried out the circle configuration is obtained. For example, when it is used for the excitation light source for solid state laser, while raising the optical conversion efficiency from excitation light to oscillation light and obtaining a good oscillation output beam, it aims at the amendment method of a laser beam and equipment which have been improved so that the achievement means can provide comparatively cheaply.

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MEANS

[Means for Solving the Problem] In order to solve the technical problem, by amendment method of a laser beam by this invention As opposed to a laser beam to which outgoing radiation of the luminescence side was carried out from a source of laser luminescence which has a longitudinal direction and the direction of a short hand After collimating the 2nd direction component of a beam which met in the direction of a short hand of a luminescence side almost in parallel While making the inside of each light guide plate transmit where it carried out incidence to an optical-path division element which installed two or more light guide plates in the 1st direction which met a longitudinal direction of a luminescence side in this beam and the 1st direction component of a beam is divided While outgoing radiation is carried out from each light guide plate where displacement of each division beam is carried out by predetermined width of face in the 2nd direction, and carrying out incidence of each of this division beam to an optical-path modification element which installed two or more light guide plates in the 2nd direction It was made to condense each division beam which was made to carry out and change outgoing radiation into the condition of having made an optical path of the 1st direction component changing within each light guide plate, and having piled up each division beam in the outgoing radiation side edge section, and carried out outgoing radiation from this optical-path modification element.

[0013] In an amendment method of said laser beam, said optical-path modification element and an optical-path modification element can acquire said optical path of each division beam by setup [which / of whenever / in each light guide plate / incident angle /, an outgoing radiation angle, an outgoing radiation location, or a refractive index].

[0014] A collimation element for which a luminescence side collimates the 2nd direction component which met in the direction of a short hand of a luminescence side to a laser beam by which outgoing radiation is carried out from a source of laser luminescence which has a longitudinal direction and the direction of a short hand almost in parallel in a compensator of a laser beam by this invention, While making the inside of each light guide plate transmit where the 1st direction component in alignment with a longitudinal direction of a luminescence side is divided An optical-path division element which installed two or more light guide plates in the 1st direction that outgoing radiation of each division beam should be carried out where displacement is carried out by predetermined width of face in the 2nd direction, An optical-path modification element which installed two or more light guide plates in the 2nd direction, and a condensing element which condenses each division beam which carried out outgoing radiation from an optical-path modification element are provided that outgoing radiation should be carried out and carried out to the condition of having made an optical path of the 1st direction component of each division beam changing, and having piled up in the outgoing radiation side edge section.

[0015] In a compensator of said laser beam, said optical-path division element and an optical-path modification element can acquire said optical path of each division beam by forming each light guide plate which made parallel an incidence side edge side and an outgoing radiation side edge side of a beam with a glass plate or an optical-crystal board.

[0016] At least as one of elements, although a thing of a mode of said optical-path division element and an optical-path modification element which was made to carry out displacement at a predetermined angle, and installed each light guide plate so that whenever [incident angle] might differ from an outgoing radiation angle one by one can be used In this case, an optical-path division element and an optical-path modification element which can be set It can constitute from each light guide plate of isomorphism which carried out the shape of a rectangle containing a parallelogram, and each light guide plate of an optical-path modification element can shift an angle on a field which is parallel to the 1st direction, respectively on a field where each light guide plate of an optical-path division element is parallel to the 2nd direction, and it can arrange in the shape of a sector, and can carry out.

[0017] Moreover, at least, as one of elements, although a thing of a mode which installed each light guide plate of said optical-path division element and an optical-path modification element into which length was changed so that whenever [incident angle], and an outgoing radiation angle might be fixed and outgoing radiation locations of a beam might differ one by one can also be used In this case, an optical-path division element and an optical-path modification element which can be set Constitute from each light guide plate which carried out the shape of a rectangle containing a parallelogram, and while arranging each light guide plate of an optical-path division element in the condition of having made an incidence side and an outgoing radiation side edge side inclining toward an incidence side at a predetermined angle on a field which is parallel to the 2nd direction Each light guide plate of an optical-path modification element can arrange and carry out an incidence side and an outgoing radiation side edge side in the condition of having made a predetermined angle inclining toward an outgoing radiation side, on a field which is parallel to the 1st direction.

[0018] Furthermore, at least, as one of elements, although a thing of a mode which installed each light guide plate of said optical-path division element and an optical-path modification element into which a refractive index was changed so that whenever [incident angle], and an outgoing radiation angle might be fixed and refractive indexes of a beam might differ one by one can also be used In this case, said optical-path division element and an optical-path modification element which can be set Constitute from each light guide plate of isomorphism which carried out the shape of a rectangle containing a parallelogram, and while arranging each light guide plate of an optical-path division element in the condition of having made an incidence side and an outgoing radiation side edge side inclining toward an outgoing radiation side at a predetermined angle on a field which is parallel to the 2nd direction Each light guide plate of an optical-path modification element can arrange and carry out an incidence side and an outgoing radiation side edge side in the condition of having made a predetermined angle inclining toward an incidence side, on a field which is parallel to the 1st direction.

[0019] A means to carry out total reflection of the laser beam by front reverse side both sides of each light guide plate, and to restrict an optical path of a division beam is given, and few air spaces are prepared between each light guide plate as this optical-path limit means, or an optical-path division element in a compensator of said laser beam was coated with a metal membrane or a dielectric film.

[0020] In addition, there is not only a mode that uses a thing of a configuration similarly as said optical-path division element and an optical-path modification element but a mode used combining a thing of a configuration of having differed.

[0021]

[Embodiment of the Invention] Below, it is attached to the amendment method of a laser beam and equipment by this invention, and drawing 1 -5 attached explain in detail based on the suitable operation gestalt applied to the excitation light source for solid state laser which used semiconductor laser.

[0022] Although a plan shows (a) and (b) shows the basic configuration of the amendment method by the 1st operation gestalt, and equipment with front view by drawing 1 , respectively Semiconductor laser 1, the collimation element 2, the optical-path division element 3, the optical-path modification element 4, and the condensing element 5 are used for this 1st operation gestalt, and the semiconductor laser 1 which is a source of laser luminescence is used for it in the condition of having made the longitudinal direction of a luminescence side extending horizontally, and having arranged it.

[0023] The so-called diode laser bar which equipped semiconductor laser 1 with the oblong luminescence side which installed many diode laser light emitting devices horizontally is used. For the collimation element 2 The fiber lens or cylindrical lens formed in the shape of a cylinder is used oblong. As opposed to the laser beam to which it has arranged in the shape of opposite in the condition of having made the collimation element 2 approaching the luminescence side of semiconductor laser 1, and outgoing radiation of this collimation element 2 was carried out from semiconductor laser 1 The laser beam by which outgoing radiation was carried out [of the perpendicular direction component, i.e., a luminescence side,] with breadth from the short hand is collimated almost in parallel, and outgoing radiation is carried out to the optical-path division element 3 side.

[0024] The optical-path division element 3 arranges the light guide plate 3-1 which carried out the shape of a rectangle of two or more sheets (drawing 1 three sheets) formed with the optical crystal into which it processed glass plates, such as optical glass and quartz glass, or tabular, 3-2, and 3-3 in the shape of side-by-side installation. Incidence of the horizontal component of the laser beam by which the perpendicular direction component was collimated, i.e., the laser beam by which outgoing radiation was carried out with breadth from the longitudinal direction of a luminescence side, is carried out in the condition of having divided into each light guide plate 3-1, 3-2, and 3-3. A division laser beam turns to the optical-path modification element 4 side the inside of the optical path regulated with each light guide plate, and he is trying to be transmitted, respectively.

[0025] The optical-path division element 3 meets horizontally, and installs each light guide plate 3-1 which extends perpendicularly that it should correspond to the broad horizontal component of a laser beam, 3-2, and 3-3. And while it installs on a vertical plane where displacement of the angle is carried out to the shape of a sector one by one so that whenever [incident angle / of the laser beam to the incidence side edge side of each light guide plate] may differ, respectively, and both sides of each light guide plate are ground so that light may not reflect irregularly [whether it installs, where the crevice more than a wavelength gap (air space) is prepared so that the division laser beam which passes each light guide plate may carry out total reflection in a side-by-side installation interface, and] Giving the reflector by the metal membrane or the dielectric film at least to one side of a light guide plate, each light guide plate lessens the reflective loss further by grinding the incidence side edge side and outgoing radiation side edge side of a laser beam, respectively, and giving an antireflection film.

[0026] Therefore, although the division laser beam by which incidence was carried out to each light guide plate 3-1 of the optical-path division element 3, 3-2, and 3-3 is transmitted towards the optical-path modification element 4 side, respectively while a horizontal component carries out total reflection of the inside of the narrow optical path restricted by the thickness width of face of each light guide plate Since outgoing radiation of the division laser beam which the perpendicular direction component was transmitted receiving optical-path change perpendicularly within each light guide plate, and passed each light guide plate will be carried out in the condition of having distributed in height which is different to a perpendicular direction, respectively This distribution is lessened, whenever [said displacement angle / of each light guide plate to install] is set up beforehand, and outgoing radiation is made to be carried out by the collimated beam of the predetermined width of face which suits each light guide plate of the optical-path modification element 4 so that the degree with which each division laser beam is perpendicular and

which it does not overlap may be approached.

[0027] Although incidence of the division laser beam which passed each light guide plate 3-1 of the optical-path division element 3, 3-2, and 3-3 is carried out to the optical-path modification element 4 arranged in the latter part, respectively This optical-path modification element 4 arranges the light guide plate 4-1 which carried out the shape of a rectangle of two or more sheets (drawing 1 three sheets) formed with the optical crystal into which it processed glass plates, such as optical glass and quartz glass, or tabular like the optical-path division element 3 of the preceding paragraph, 4-2, and 4-3 in the shape of side-by-side installation. Each light guide plate 4-1 which extends horizontally that it should correspond after 90 degrees has rotated with each light guide plate of the optical-path division element 3 (i.e., a division laser beam), 4-2, and 4-3 are installed along a perpendicular direction. And on the horizontal plane, where displacement of the angle is carried out to the shape of a sector one by one, it is installed, so that whenever [incident angle / of the division laser beam to the incidence side edge side of each light guide plate] may differ, respectively.

[0028] Therefore, although transmitted incidence of the division laser beam which passed each perpendicular light guide plate 3-1 of the optical-path division element 3, 3-2, and 3-3 being carried out to each level light guide plate 4-1 of the optical-path modification element 4, 4-2, and 4-3, respectively, and receiving optical-path change horizontally within each light guide plate of the optical-path modification element 4 concerned In order to make easy condensing by the condensing element 5 prepared in the latter part of the optical-path modification element 4, whenever [displacement angle / of each light guide plate to install] is beforehand set up so that the division laser beam which passed each light guide plate may be horizontal in an outgoing radiation side edge side and may overlap. [0029] In addition, since there is not necessarily no need of preparing an air space between each light guide plate like [in the case of the optical-path modification element 3], or performing coating, such as a metal membrane and a dielectric film, to a surface of light-guard plate, and carrying out total reflection since there are very few amounts to which, as for the angle of divergence of the perpendicular direction component in each light guide plate of the optical-path modification element 4, a laser beam is equivalent to ** and vertical both sides of a light guide plate generally and small (<0.5 degree), it is also omissible.

[0030] Although outgoing radiation of the laser beam which passed each light guide plate of the optical-path modification element 4 is carried out towards the condensing element 5 prepared in the latter part This condensing element 5 has for example, cylindrical-lens 5a and aspheric lens 5b. Once making parallel outgoing radiation light from the optical-path modification element 4 by cylindrical-lens 5a A horizontal component and a perpendicular direction component are narrowed down by aspheric lens 5b, respectively, and it is condensed by Focus F, and the focal F location of a horizontal component and a perpendicular direction component in that case is beforehand amended so that a gap may not arise by said cylindrical-lens 5a: horizontally made the beam diameter of a laser beam.

[0031] Since the substantial diameter of an incident beam of a horizontal component to said condensing element 5 is inversely proportional to the number of partitions (namely, the number of light guide plates) and short Can make small the horizontal beam diameter when condensing with the condensing element 5 by the ratio to which the diameter of an incident beam became small, and the perpendicular direction component of a laser beam is received. Although some condensing nature of the perpendicular direction when a substantial outgoing radiation beam diameter becoming long where two or more division laser beams are perpendicularly located in a line, and condensing with the condensing element 5 is spoiled Since an angle of divergence is small and close to parallel light from the first, it will come out, if the number of partitions (namely, the number of light guide plates) is set below to the suitable value, and it does not become larger than the beam diameter of a horizontal component, and does not become a problem on practical use.

[0032] For example, if it is made the parallelism (it is fully a possible value even if this uses a commercial collimation element.) of about 0.5 degrees by the collimation to a perpendicular direction component when the luminescence side of semiconductor laser 1 is 10mm(level) x 1micrometer (perpendicular), the beam diameter of a perpendicular direction component will not become [the number of partitions of the horizontal component by the optical-path division element 3] a problem practically to 20 division (20 light guide plates are installed) degree.

[0033] If this is fitted to the operation gestalt of drawing 1 using the light guide plate of three sheets as the optical-path division element 3 and an optical-path modification element 4, respectively and is described concretely About a horizontal component, a light guide plate 4-1 and the division laser beam which carried out outgoing radiation from 4-3 lap with the division laser beam of a light guide plate 4-2. Since the horizontal beam diameter seen from the condensing element 5 side becomes the abbreviation 1/3 of the width of face of a light guide plate 4-2, and the width of face of a luminescence side [in / it is almost equal and / the horizontal direction of semiconductor laser 1], the original abbreviation 1/3 can be made to condense the horizontal beam diameter of a laser spot by the condensing element 5.

[0034] Moreover, although it will be about 3 times the path which collimated immediately after carrying out outgoing radiation from semiconductor laser 1, since the original parallelism of the beam diameter of the perpendicularly outgoing radiation is carried out from each light guide plate of the optical-path division element 3 is generally 50 or more times good compared with a horizontal component, even if the condensing nature of a perpendicular direction component is somewhat spoiled by the optical-path division element 3, it does not pose a problem substantially.

[0035] The optical-path division element 3 which divides and transmits the horizontal component of a laser beam with the 1st operation gestalt explained above, Although these the 1st and optical-path modification elements 3 and 4 were constituted from a light guide plate which carried out the shape of two or more rectangle installed in the condition of having shifted to the flabellate form using the optical-path modification element 4 which piles up the

horizontal component of this division laser beam so that incident angles might differ. Change length, or change the refractive index of each light guide plate, it is made for angle of refraction to differ, as it is made the same and the outgoing radiation locations from each light guide plate differ, and the incident angle to each light guide plate has other operation gestalten similarly operated with the 1st operation gestalt.

[0036] For example, length is changed so that the beam incident angle to each light guide plate of an optical-path division element and an optical-path modification element may be made equal in drawing 2 and the outgoing radiation locations from each light guide plate may differ. A plan shows (a) and (b) shows the basic configuration of the 2nd operation gestalt similarly operated with the 1st operation gestalt with front view, respectively. The semiconductor laser 1 same with this operation gestalt as the case of the 1st operation gestalt, While the collimation element 2 and the condensing element 5 are used, the optical-path division element 6 replaced with the optical-path division element 3 and the optical-path modification element 7 replaced with the optical-path modification element 4 are used, but detailed explanation is omitted if attached to the common semiconductor laser 1, the collimation element 2, and the condensing element 5.

[0037] The optical-path division element 6 each light guide plate 6-1 of two or more sheets (drawing 2 three sheets) of the shape of a parallelogram which extends perpendicularly, 6-2, and 6-3 While changing an incidence side edge side into an alignment condition so that an incidence side edge side and an outgoing radiation side edge side may meet horizontally, and may install on a vertical plane in the mode which inclines in an incidence side and whenever [incident angle / of the laser beam to the incidence side edge side of each light guide plate] may become equal, respectively It is installed in the condition that change the length of each light guide plate 6-1, 6-2, and 6-3, and an outgoing radiation side edge side becomes stair-like so that outgoing radiation locations may differ one by one.

[0038] Although transmitted towards the optical-path modification element 7 side by this, respectively, carrying out total reflection of the inside of the narrow optical path to which the horizontal component was restricted by the thickness width of face of each light guide plate, as for the division laser beam by which incidence was carried out to each light guide plate 6-1 of the optical-path division element 6, 6-2, and 6-3 Since outgoing radiation of the division laser beam which the perpendicular direction component was transmitted receiving optical-path change perpendicularly within each light guide plate, and passed each light guide plate will be carried out in height which is different to a perpendicular direction, respectively So that this distribution may be lessened and the degree with which each division laser beam is perpendicular in an outgoing radiation side edge side and which it does not overlap may be approached Whenever [said tilt-angle / of the length of each light guide plate to install, an incidence side edge side, and an outgoing radiation side edge side] is set up beforehand; and outgoing radiation is made to be carried out as a collimated beam of the predetermined width of face which suits each light guide plate of the optical-path modification element 7.

[0039] The optical-path modification element 7 each light guide plate 7-1 in the condition, i.e., the shape of a parallelogram which extends horizontally, that 90 degrees rotated with each light guide plate of the optical-path division element 6, 7-2, and 7-3 While changing an incidence side edge side into an alignment condition so that an incidence side edge side and an outgoing radiation side edge side may install along a perpendicular direction in the mode which inclines in an outgoing radiation side on a horizontal plane and whenever [incident angle / of the laser beam to the incidence side edge side of each light guide plate] may become equal, respectively It is installed in the condition that change the length of each light guide plate 7-1, 7-2, and 7-3, and an outgoing radiation side edge side becomes stair-like so that outgoing radiation locations may differ one by one.

[0040] Although the division laser beam by which passed each light guide plate of the optical-path division element 6, and incidence was carried out by this to each light guide plate 7-1 of the optical-path modification element 7, 7-2, and 7-3, respectively is transmitted receiving optical-path change horizontally within each light guide plate of the optical-path modification element 7 concerned In order to make easy condensing by the condensing element 5 prepared in the latter part of the optical-path modification element 7, whenever [tilt-angle / of each light guide plate to install], and length are beforehand set up so that the division laser beam which passed each light guide plate may be horizontal in an outgoing radiation side edge side and may overlap.

[0041] Furthermore, in drawing 4, change the refractive index of each light guide plate of an optical-path division element and an optical-path modification element, and it is made for angle of refraction to differ. A plan shows (a) and (b) shows the basic configuration of the 3rd operation gestalt similarly operated with the 1st operation gestalt with front view, respectively. The semiconductor laser 1 same with this operation gestalt as the case of the 1st operation gestalt, While the collimation element 2 and the condensing element 5 are used, the optical-path division element 8 replaced with the optical-path division element 3 and the optical-path modification element 9 replaced with the optical-path modification element 4 are used, but detailed explanation is omitted if attached to the common semiconductor laser 1, the collimation element 2, and the condensing element 5.

[0042] The optical-path division element 8 each light guide plate 8-1 of two or more sheets (drawing 2 three sheets) with which refractive indexes differ by the shape of a rectangle which extends perpendicularly, respectively, 8-2, and 8-3 On a vertical plane, in the mode which sees from an incidence side and inclines at a predetermined angle (for example, 45 degrees) in the shape of an elevation angle, an incidence side edge side and an outgoing radiation side edge side meet horizontally, and install. And while changing an incidence side edge side into an alignment condition and being installed so that whenever [incident angle / of the laser beam to the incidence side edge side of each light guide plate] may become equal, respectively, each light guide plate 6-1, 6-2, and 6-3 are *****ed) in what changed the refractive index so that angle of refraction might differ.

[0043] Although transmitted towards the optical-path modification element 9 side by this, respectively, carrying out total reflection of the inside of the narrow optical path to which the horizontal component was restricted by the thickness width of face of each light guide plate, as for the division laser beam by which incidence was carried out to each light guide plate 8-1 of the optical-path division element 8, 8-2, and 8-3 Since outgoing radiation of the division laser beam which the perpendicular direction component was transmitted receiving optical-path change perpendicularly by whenever [corresponding to the refractive index of each light guide plate / angle-of-refraction], and passed each light guide plate will be carried out in the condition of having distributed in height which is different to a perpendicular direction, respectively The refractive index of each light guide plate to install is beforehand set up so that this distribution may be lessened and the degree with which each division laser beam is perpendicular and which it does not overlap may be approached (for example, in drawing 3 , the refractive index of a light guide plate 8-1 is the smallest, and the largest in the refractive index of a light guide plate 8-3).

[0044] The optical-path modification element 9 each light guide plate of the optical-path division element 8, each light guide plate 9-1 by the same configuration, 9-2, and 9-3 If incidence of the division laser beam from which height differs to perpendicularly which it is used where [level] 90 degrees is transferred, and passed each light guide plate of the optical-path division element 8 is carried out to each light guide plate 9-1, 9-2, and 9-3, respectively Although the horizontal component of this division laser beam is transmitted receiving optical-path change horizontally by whenever [corresponding to the refractive index of each light guide plate / angle-of-refraction] In order to make easy condensing by the condensing element 5 prepared in the latter part of the optical-path modification element 9 The refractive index of each light guide plate is beforehand set up so that the division laser beam which passed each light guide plate may be horizontal in an outgoing radiation side edge side and may overlap (for example, in drawing 3 , the refractive index of a light guide plate 9-1 is the smallest, and the largest in the refractive index of a light guide plate 9-3).

[0045] As opposed to the laser beam by which outgoing radiation was carried out with the 1-3rd operation gestalten described above from the luminescence side of the semiconductor laser 1 which is a source of laser luminescence After making parallel the perpendicular direction (direction of short hand) component of a beam with the collimation element 2 Where the horizontal direction (longitudinal direction) component of a beam is divided, incidence is carried out to the optical-path division elements 3, 6, and 8 equipped with two or more installed light guide plates. The degree which a perpendicular direction (direction of short hand) component does not overlap in respect of an outgoing radiation side edge is made to condense the division beam to which the inside of each light guide plate of the optical-path division elements 3, 6, and 8 was made to transmit. It changes into the condition of having piled up with the optical-path modification elements 4, 7, and 9 equipped with two or more light guide plates which installed the horizontal component of this division laser beam, and is made to condense with the condensing element 5.

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EXAMPLE

[Example] Although the semiconductor laser 11 which drawing 4 shows the equipment which embodied the amendment method of the beam by the 1st operation gestalt, and serves as a source of luminescence uses 20WCW semiconductor laser (form SDL-3470-S) of an SDL company, while the luminescence length of this semiconductor laser is 1 micrometer of perpendicular directions in 10mm of horizontal directions, the angle of divergence of luminescence considers as 50 degrees of perpendicular directions at 15 degrees of horizontal directions, and luminescence wavelength is 810nm.

[0047] The laser beam which carried out outgoing radiation from semiconductor laser 11 If a gradient SHIRENDORI cull lens (Doric Lenses Inc, USA, and diameter of rod 1mmphi) is first used for the collimation means 12 to a perpendicular direction component and it collimates in parallel An angle of divergence becomes 0.4 degrees by 0.5m, and a vertical beam diameter uses two convex lenses with a focal distance of 60mm (outer-diameter 40mmphi) for a relay lens 13 after this, and it is made to serve as telecentric optical system. The collimated beam diameter (10mmx0.5mm) is expanded to twice as many 20mmx1mm as this, and the angle of divergence on an optical principle was made to become 1/2, i.e., 7.5 degreex0.2 degree.

[0048] In addition, if a beam diameter is made to expand using said relay lens 13, since thickness of the thickness of the light guide plate per one board at the time of fixing the number of partitions (number of sheets of a light guide plate) of the optical-path division element 14 used for the latter part and the optical-path modification element 15 can be carried out, although it is desirable for there to be an advantage to which manufacture including processing of the light guide plate concerned becomes easy, therefore to use a relay lens 13 on manufacture, they are not indispensable requirements theoretically.

[0049] Next, although the optical-path division element 14 which divides a horizontal component is arranged in the current beam position which expanded the incidence end face twice In order that it may be used where nine quartz plates with a thickness of 2.3mm are put on this optical-path modification element 14 by magnitude 50mmx50mm as a light guide plate, and each light guide plate 16-1 to 16-9 may change the incident angle to the light guide plate end face of an incident beam, respectively As shown by a diagram, where displacement is carried out to a flabellate form on a vertical plane, it was installing, but whenever [displacement angle] was set up so that an outgoing radiation beam might shift perpendicularly every 2.3mm, respectively.

[0050] The reason for having set whenever [displacement angle] as 2.3mm the optical-path modification element 15 which piles up the divided horizontal component If it is for making it the same configuration as the optical-path division element 14, and aiming at reduction of manufacture cost and thickness of each light guide plate of the optical-path division element 14 is set to 2mm Although what is necessary is just to have decided whenever [displacement angle / of the optical-path modification element 14] that a gap is also set to 2mm, since incidence of the beam was not carried out independently unless it made thickness of each light guide plate of the optical-path modification element 15 larger than the path of the perpendicular direction component of each beam from the optical-path division element 14, it set up in consideration of the surplus size for it.

[0051] Although coating of dielectric multilayers which carries out total reflection to the beam of 80 degrees or more of incident angles is performed to both sides of the optical-path division element 14 Coating of these dielectric multilayers is not for carrying out total reflection of the beam within a light guide plate. It is a cure for reflecting some beams which hit the light guide plate which adjoins after carrying out outgoing radiation from a light guide plate, and lessening transmission loss. Moreover, although the antireflection film is given to the both-ends side (close outgoing radiation side) of each light guide plate as a cure for lessening transmission loss, and it installed between each light guide plate further where the air space which is about 50 micrometers is prepared so that a beam might carry out total reflection within a light guide plate Each of these is the means for improving the engine performance or productivity, and is not involved in the essence of invention.

[0052] Although the optical-path modification element 15 is for piling up each beam to a horizontal component, and the thing of the same configuration as the optical-path division element 14 is used here where 90-degree displacement of the side-by-side installation arrangement is carried out Unlike the case of the optical-path modification element 14, since vertical parallelism is very good If some losses are permitted, it is not necessary to necessarily carry out beam total reflection within a light guide plate. Therefore, it is also possible to install in the state of adhesion as it is without preparing an air space between each light guide plate or attaching a total reflection coat. Moreover, it is necessary to adjust the angle of a light guide plate, thickness, and the refractive index of each light guide plate although it is not necessary to also make a configuration the same as the optical-path division element 14, however so that the gap of each light guide plate may be made the same as the gap of a gap of the

beam by the optical-path division element 14, and it may see from a horizontal direction and a beam may lap.

[0053] The diameter of outgoing radiation can consider by 2.3mm that the condition of a beam is the thing of 7.5 degrees of angles of divergence seen from a horizontal direction according to the above amendment optical system. Moreover, since outgoing radiation of each beam will be carried out at the angle of 0.2 degrees from each light guide plate of the optical-path modification element 15 if it sees from a perpendicular direction Since it is inversely proportional to approximate value at the diameter of a spot which the diameter of outgoing radiation can consider to approximate value that is the beam of 0.2 degrees of angles of divergence by 20.7mm (2.3mmx9 light guide plate), namely, the product of the diameter of outgoing radiation and an angle of divergence can condense according to the optical principle The condensing nature of a horizontal beam will be improved about 10 times compared with the case where this amendment optical system is not used.

[0054] Although cylindrical convex lens 16a and aspheric lens 16b are arranged in the latter part of the optical-path modification element 15 as a condensing element 16 and it is made to condense A focal distance makes cylindrical-lens 16a the magnitude of 30x30mm by 200mm. A focal distance lens 16b as 50mm (the numerical aperture at the time of condensing being horizontal about 0.29, about 0.24) Especially cylindrical convex lens 16a is used in order to make the minimum spot location of a horizontal and perpendicular both directions in agreement on an optical axis.

[0055] The path of the beam spot in the minimum spot location which condensed with the condensing element 16 was set to 500micrometer(level) x400micrometer (perpendicular) by the result measured using the beam profiler, it could condense to the beam spot suitable for the excitation light of solid state laser, and ** of the permeability of these optical system was also very as good as 88%.

[0056] Moreover, although the solid state laser shown by drawing 5 by making into the excitation light source 17 the semiconductor laser which used said amendment optical system was manufactured This solid state laser uses Nd:YVO4 (the concentration of Nd is 1% of thing at the configuration of 3x3x1mm) as a laser medium 18. While performing coating which carries out total reflection to a field (condenser lens side) to the wavelength of 1064nm on the other hand and which is penetrated about 100% to the wavelength of 810nm Antireflection coating to the wavelength of 1064nm is carried out to an another side. It is made for the beam spot to make a 500micrometer (level) x400micrometer (perpendicular) laser beam condense [wavelength / which was obtained by the aforementioned condensing method in the laser medium 18] as an excitation light 19 by 810nm. While using a concave mirror with a curvature of 1m for the output mirror 20 at 95% (5% of permeability) of reflection factors, the cavity length between the laser medium 18 and the output mirror 20 is set as 150mm.

[0057] In this solid state laser, when incidence power (excitation power) of the excitation light 19 to the laser medium 18 is set to 15W. Output power with a wavelength of 1064nm which is the oscillation light 21 by which outgoing radiation was carried out through the output mirror 20 is 6W. Therefore, even if 40% and high conversion efficiency are acquired and compare with the end-face excitation method using the optical-fiber bunch of the above mentioned conventional technology as optical conversion efficiency, are so much equal. ** of the optical-path division element and optical-path modification element which installed the light guide plate of a glass plate in cost is also far cheap compared with an optical-fiber bunch.

[Translation done.]

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] A plan shows (a) and (b) shows the basic configuration by the 1st operation gestalt which applied the amendment method of the laser beam of this invention, and equipment with front view, respectively.

[Drawing 2] A plan shows (a) and (b) shows the basic configuration by the 2nd operation gestalt which applied the amendment method of the laser beam of this invention, and equipment with front view, respectively.

[Drawing 3] A plan shows (a) and (b) shows the basic configuration by the 3rd operation gestalt which applied the amendment method of the laser beam of this invention, and equipment with front view, respectively.

[Drawing 4] The 1st operation gestalt which applied the amendment method of the laser beam of this invention and equipment is made more concrete, a plan shows (a) and front view shows (b), respectively.

[Drawing 5] It is explanatory drawing of the solid state laser which made the equipment of drawing 4 the excitation light source.

[Description of Notations]

1 11 Semiconductor laser

2 12 Collimation element

3, 6, 8, 14 Optical-path division element

4, 7, 9, 15 Optical-path modification element

5 16 Condensing element

13 Relay Lens

17 Excitation Light Source

18 Laser Medium

19 Excitation Light

20 Output Mirror

21 Oscillation Light

[Translation done.]

(19)日本国特許庁 (J P)

(12) 特 許 公 報 (B 2)

(11)特許番号

特許第3098200号
(P3098200)

(45)発行日 平成12年10月16日 (2000. 10. 16)

(24)登録日 平成12年 8 月11日 (2000. 8. 11)

(51)Int.Cl.⁷

識別記号

F I

G 0 2 B 27/09

G 0 2 B 27/00

E

請求項の数11(全 10 頁)

(21)出願番号 特願平8-350727

(22)出願日 平成 8 年12月27日 (1996. 12. 27)

(65)公開番号 特開平10-186246

(43)公開日 平成10年 7 月14日 (1998. 7. 14)

審査請求日 平成10年 8 月20日 (1998. 8. 20)

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(56)参考文献 国際公開96/21877 (WO, A 1)

(58)調査した分野(Int.Cl.⁷, D B 名)

G02B 27/09

(54)【発明の名称】 レーザビームの補正方法及び装置

1

(57)【特許請求の範囲】

【請求項 1】 発光面が長手方向と短手方向を有するレーザ発光源から出射されたレーザビームに対し、発光面の短手方向に沿ったビームの第2方向成分をほぼ平行にコリメートした後に、このビームを発光面の長手方向に沿った第1方向へ複数の導光板を並設した光路分割素子に入射させて、ビームの第1方向成分を分割した状態で各導光板内を伝送させると共に、各分割ビームを第2方向へ所定幅で変位させた状態で各導光板から出射させ、この各分割ビームは第2方向へ複数の導光板を並設した光路変更素子に入射させると共に、各導光板内で第1方向成分の光路を変更させて各分割ビームを出射側端部で重ね合わせた状態にして出射させ、この光路変更素子から出射させた各分割ビームを集光することを特徴としたレーザビームの補正方法。

2

【請求項 2】 前記光路変更素子と光路変更素子は、各導光板における入射角度と出射角度、又は出射位置、又は屈折率の何れかの設定により、各分割ビームの前記光路を得るようにした請求項 1 に記載したレーザビームの補正方法。

【請求項 3】 発光面が長手方向と短手方向を有するレーザ発光源から出射されるレーザビームに対し、発光面の短手方向に沿った第2方向成分をほぼ平行にコリメートするコリメート素子と、発光面の長手方向に沿った第1方向成分を分割した状態で各導光板内を伝送させると共に、各分割ビームを第2方向へ所定幅で変位させた状態で出射すべく、複数の導光板を第1方向へ並設した光路分割素子と、各分割ビームの第1方向成分の光路を変更させて出射側端部で重ね合わせた状態にして出射すべく、複数の導光板を第2方向へ並設した光路変更素子

と、光路変更素子から出射させた各分割ビームを集光する集光素子と、を具備することを特徴としたレーザビームの補正装置。

【請求項4】 前記光路分割素子と光路変更素子は、ビームの入射側端面と出射側端面を平行にした各導光板で構成され、各導光板をガラスプレート又は光学結晶板で形成した請求項3に記載したレーザビームの補正装置。

【請求項5】 前記光路分割素子と光路変更素子の少なくとも何れか一方の素子は、入射角度及び出射角度が順次異なるように所定角度で変位させて各導光板を並設した請求項4に記載したレーザビームの補正装置。

【請求項6】 前記光路分割素子と光路変更素子は、平行四辺形を含む方形をした同形の各導光板で構成され、光路分割素子の各導光板は第2方向と平行する面上において、光路変更素子の各導光板は第1方向と平行する面上において、それぞれ角度をずらせて扇形状に配列した請求項5に記載したレーザビームの補正装置。

【請求項7】 前記光路分割素子と光路変更素子の少なくとも何れか一方の素子は、入射角度及び出射角度が一定でビームの出射位置が順次異なるように長さを変えた各導光板を並設した請求項4に記載したレーザビームの補正装置。

【請求項8】 前記光路分割素子と光路変更素子は、平行四辺形を含む方形の各導光板で構成され、光路分割素子の各導光板は第2方向と平行する面上において、入射側及び出射側端面を入射側へ所定角度に傾斜させた状態で配置すると共に、光路変更素子の各導光板は第1方向と平行する面上において、入射側及び出射側端面を出射側へ所定角度に傾斜させた状態で配置する請求項7に記載したレーザビームの補正装置。

【請求項9】 前記光路分割素子と光路変更素子の少なくとも何れか一方の素子は、入射角度及び出射角度が一定でビームの屈折率が順次異なるように屈折率を変えた各導光板を並設した請求項4に記載したレーザビームの補正装置。

【請求項10】 前記光路分割素子と光路変更素子は、平行四辺形を含む方形をした同形の各導光板で構成され、光路分割素子の各導光板は第2方向と平行する面上において、入射側及び出射側端面を出射側へ所定角度に傾斜させた状態で配置すると共に、光路変更素子の各導光板は第1方向と平行する面上において、入射側及び出射側端面を入射側へ所定角度に傾斜させた状態で配置する請求項9に記載したレーザビームの補正装置。

【請求項11】 前記光路分割素子には、各導光板の表裏両面でレーザビームを全反射させて分割ビームの光路を制限させる手段を施し、この光路制限手段として各導光板間にわずかな空気層を設けるか、金属膜または誘電体膜をコーティングした請求項3～11の何れかに記載したレーザビームの補正装置。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、特に半導体レーザから発生させたレーザビームのように、一方に広がった楕円状などの非円形なレーザビームを、容易且つ安価な手段によって小径な円形状ビームスポットに集光できるように補正するレーザビームの補正方法及び装置に関するものであり、例えば半導体レーザ励起固体レーザの励起用光源などとして理科学研究、マイクロレーザ加工、製版、医療、その他の各種分野で利用することができる。

【0002】

【従来の技術】この種のレーザビームは、特殊な用途を除いて一般に集光が容易で且つ高密度のビームにする必要があり、そのためにはビームスポットが円形状なるべく小径であることが望ましく、例えば高出力半導体レーザのレーザビームを励起光として固体レーザを励起する場合には、固体レーザの媒質端面から入射するレーザビームが高密度で且つ固体レーザの発振光と等しいビームスポットで集光させると、高い光変換効率で且つ良質な発振出力ビームが得られることが一般に知られており、そのためにはレーザビームをレーザ媒体内に於て数百 μm の円形状をしたビームスポットで集光させることが望ましい。

【0003】しかしながら、例えば多数の発光素子を並列にしたレーザダイオードバーと呼ばれる半導体レーザの発光面は、一方に長く（例えば10～20W出力の半導体レーザでは発光長が10mm）で、他方が短い（例えば発光長が1 μm ）ので、発光面から出射されるレーザビームのビームスポットは楕円状になり、このレーザビームを所望のビームスポットに集光させる場合には、短手方向成分は容易に小さいビーム径（数十 μm 以下）に集光することができるが、長手方向成分に対してはシリンドリカルレンズ、球面レンズ、非球面レンズ等を組み合わせた通常の光学的集光方法では小さく絞ることがきわめて困難であり、3mm程度のビーム径になってしまう。

【0004】なお、以下の説明では前記半導体レーザの発光面が横長になるように長手方向を水平にした状態、即ち発光面の長手方向に沿った第1方向が水平面で短手方向に沿った第2方向が垂直面とした状態で使用する場合について説明するが、例えば水平方向の発光長が10mmのビームを1mm ϕ 以下に集光することは前記の理由から不可能であり、そのために半導体レーザ励起固体レーザに用いた場合に高い光変換効率を得にくいばかりか、ビームスポットが楕円状になると発振出力ビームも楕円状になって高品質のレーザビームが得られない。

【0005】前記課題を解決する手段の一つとして、例えば特開平5-93828号公報などに開示されている光ファイバー束を用いた端面励起方法があり、この方法では半導体レーザの出力放射を平行化するコリメート素

子に、一端側が分離状態で水平方向に並設されて他端側が円形状に結束された多数（半導体レーザの発光素子と同数）の光ファイバー束を結合し、前記半導体レーザの発光面に近接させたコリメートレンズによって、ダイオードバーを構成する個々の発光素子からの出射光をまず垂直方向に集光して平行にコリメートした後に、この出射光を並設した光ファイバー束の一端側から入射させて結束した他端側から出射させると、レーザビームは水平方向と垂直方向のビームが平均化された円形状で径の小さいビームスポットが得られる。

【0006】前記端面励起方法による集光では、例えば、直径10mm（広がり角 15° ） \times 1 μ m（広がり角 50° ）の半導体レーザに光ファイバー束を組み合わせて使用すると、600 μ m径の領域から広がり角 23° （開口数NA=0.2）でレーザビームが出射され、例えばこのレーザビームを開口数NA=0.2の非球面レンズで集光させると、約600 μ mの円形状のビームにすることができ、光ファイバー束を用いないで開口数NA=0.2のレンズのみで集光した場合における水平方向のビーム径約6mmに比べて著しく集光性が改善される。

【0007】因みに、例えば出力20Wの半導体レーザ（波長808nm）2個を励起光源とし、前記端面励起方法による集光手段を介して発振波長1064nmのレーザ媒体Nd:YVO₄を用いた固体レーザに照射すると、励起光から発振光への光変換効率として約50%の値が得られている。

【0008】また、半導体レーザの集光性を改善する他の手段として、水平方向については集光させずに垂直方向のみ集光させるように、半導体レーザの出射光をロッド形状をしたレーザ媒質の側面から入力射させて励起する側面励起方法も用いられているが、この方法ではレーザ発振光の領域以外の部分でもレーザビームが吸収されるので、前記光ファイバー束を用いた端面励起方法に比べて光変換効率長が低く、一般に20%程度の光変換効率しか期待できない。

【0009】

【発明が解決しようとする課題】従来の技術における前者すなわち光ファイバー束を用いた側面励起方法によると、ビームスポットを小径の円形状にすることができるので、このレーザビームを例えば固体レーザ用励起光源に使用すると、励起光から発振光への光変換効率を高めることができる利点はあるが、光ファイバー束の製作に多くの費用及び時間を必要とし、例えば20Wクラスの半導体レーザ励起光源について製作コストの比較をすると、前記光ファイバー束を使用することによって製作コストが約2倍に高騰する。

【0010】また、従来の技術における後者すなわち水平方向の集光を行わない側面励起方法によると、製作コストが安価で簡便に実施できる利点はあるが、前記吸収

によるロスが多くて高い光変換効率を期待することができない。

【0011】そこで本発明では、例えば半導体レーザから出射されたレーザビームなどのように、非円形なレーザビームに対して光学的な補正を行って、円形状をした径の小さいビームスポットが得られるようにし、例えば固体レーザ用励起光源に使用した際には励起光から発振光への光変換効率を高め且つ良質な発振出力ビームが得られるようにすると共に、その達成手段が比較的安価に提供できるように改善したレーザビームの補正方法及び装置を目的としたものである。

【0012】

【課題を解決するための手段】前記した課題を解決するために、本発明によるレーザビームの補正方法では、発光面が長手方向と短手方向を有するレーザ発光源から出射されたレーザビームに対し、発光面の短手方向に沿ったビームの第2方向成分をほぼ平行にコリメートした後に、このビームを発光面の長手方向に沿った第1方向へ複数の導光板を並設した光路分割素子に入射させて、ビームの第1方向成分を分割した状態で各導光板内を伝送させると共に、各分割ビームを第2方向へ所定幅で変位させた状態で各導光板から出射させ、この各分割ビームは第2方向へ複数の導光板を並設した光路変更素子に入射させると共に、各導光板内で第1方向成分の光路を変更させて各分割ビームを出射側端部で重ね合わせた状態にして出射させ、この光路変更素子から出射させた各分割ビームを集光するようにした。

【0013】前記レーザビームの補正方法において、前記光路変更素子と光路変更素子は、各導光板における入射角度と出射角度、又は出射位置、又は屈折率の何れかの設定により、各分割ビームの前記光路を得ることができる。

【0014】本発明によるレーザビームの補正装置では、発光面が長手方向と短手方向を有するレーザ発光源から出射されるレーザビームに対し、発光面の短手方向に沿った第2方向成分をほぼ平行にコリメートするコリメート素子と、発光面の長手方向に沿った第1方向成分を分割した状態で各導光板内を伝送させると共に、各分割ビームを第2方向へ所定幅で変位させた状態で出射すべく、複数の導光板を第1方向へ並設した光路分割素子と、各分割ビームの第1方向成分の光路を変更させて出射側端部で重ね合わせた状態にして出射すべく、複数の導光板を第2方向へ並設した光路変更素子と、光路変更素子から出射させた各分割ビームを集光する集光素子と、を具備する。

【0015】前記レーザビームの補正装置において、前記光路分割素子と光路変更素子は、ビームの入射側端面と出射側端面を平行にした各導光板をガラスプレート又は光学結晶板で形成することにより、各分割ビームの前記光路を得ることができる。

【0016】前記光路分割素子と光路変更素子の少なくとも何れか一方の素子としては、入射角度と出射角度が順次異なるように所定角度で変位させて各導光板を並設した態様のものを使用することができるが、この場合における光路分割素子と光路変更素子は、平行四辺形を含む方形をした同形の各導光板で構成し、光路分割素子の各導光板は第2方向と平行する面上において、光路変更素子の各導光板は第1方向と平行する面上において、それぞれ角度をずらせて扇形状に配列して実施することができる。

【0017】また前記光路分割素子と光路変更素子の少なくとも何れか一方の素子として、入射角度及び出射角度が一定でビームの出射位置が順次異なるように長さを変えた各導光板を並設した態様のものも使用することができるが、この場合における光路分割素子と光路変更素子は、平行四辺形を含む方形をした各導光板で構成し、光路分割素子の各導光板は第2方向と平行する面上において、入射側及び出射側端面を入射側へ所定角度に傾斜させた状態で配置すると共に、光路変更素子の各導光板は第1方向と平行する面上において、入射側及び出射側端面を出射側へ所定角度に傾斜させた状態で配置して実施することができる。

【0018】更に前記光路分割素子と光路変更素子の少なくとも何れか一方の素子として、入射角度及び出射角度が一定でビームの屈折率が順次異なるように屈折率を変えた各導光板を並設した態様のものも使用することができるが、この場合における前記光路分割素子と光路変更素子は、平行四辺形を含む方形をした同形の各導光板で構成し、光路分割素子の各導光板は第2方向と平行する面上において、入射側及び出射側端面を出射側へ所定角度に傾斜させた状態で配置すると共に、光路変更素子の各導光板は第1方向と平行する面上において、入射側及び出射側端面を入射側へ所定角度に傾斜させた状態で配置して実施することができる。

【0019】前記レーザビームの補正装置における光路分割素子には、各導光板の表裏両面でレーザビームを全反射させて分割ビームの光路を制限する手段が施され、この光路制限手段として各導光板間にわずかな空気層を設けるか、金属膜または誘電体膜をコーティングするようにした。

【0020】なお、前記光路分割素子と光路変更素子として同様構成のものを使用する態様だけではなく、異なった構成のものを組み合わせて使用する態様もある。

【0021】

【発明の実施の形態】以下に、本発明によるレーザビームの補正方法及び装置について、半導体レーザを使用した固体レーザ用励起光源に適用した好適な実施形態に基づき、添付した図1～5によって詳しく説明する。

【0022】図1で、第1の実施形態による補正方法及び装置の基本構成を、(a)は平面図で(b)は正面図

でそれぞれ示すが、この第1の実施形態には半導体レーザ1と、コリメート素子2と、光路分割素子3と、光路変更素子4と、集光素子5とが使用され、レーザ発光源である半導体レーザ1は、発光面の長手方向を水平方向に延在させて配置した状態で使用している。

【0023】半導体レーザ1には、多数のダイオードレーザ発光素子を水平方向に並設した横長の発光面を備えた、所謂ダイオードレーザバーを用い、コリメート素子2には、円柱状に形成したファイバーレンズまたはシリンドリカルレンズを横長に使用し、半導体レーザ1の発光面にコリメート素子2を近接させた状態で対向状に配置し、このコリメート素子2が半導体レーザ1から出射されたレーザビームに対して、その垂直方向成分即ち発光面の短手方向から広がりを持って出射されたレーザビームをほぼ平行にコリメートして光路分割素子3側へ出射する。

【0024】光路分割素子3は、光学ガラスや石英ガラスなどのガラスプレート或いは板状に加工した光学結晶などで形成された複数枚(図1では3枚)の方形をした導光板3-1、3-2、3-3を並設状に配置したものであり、垂直方向成分がコリメートされたレーザビームの水平方向成分を、即ち発光面の長手方向から広がりを持って出射されたレーザビームを各導光板3-1、3-2、3-3に分割した状態で入射させ、各導光板によって規制された光路内を分割レーザビームが光路変更素子4側に向けてそれぞれ伝送されるようにしている。

【0025】光路分割素子3は、レーザビームの幅広い水平方向成分に対応すべく垂直方向に延在する各導光板3-1、3-2、3-3を水平方向に沿って並設し、且つ各導光板の入射側端面に対するレーザビームの入射角度がそれぞれ異なるように垂直面上において扇形状に順次角度を変位させた状態で並設し、各導光板の両面は光が乱反射しないよう研磨されていると共に、各導光板を通過する分割レーザビームが並設境界面で全反射するよう波長間隔以上のすき間(空気層)を設けた状態で並設するか、少なくとも導光板の片面に金属膜又は誘電体膜などによる反射面を施し、更に各導光板はレーザビームの入射側端面及び出射側端面をそれぞれ研磨して反射防止膜を施すことによって反射ロスを少なくしている。

【0026】従って、光路分割素子3の各導光板3-1、3-2、3-3に入射された分割レーザビームは、水平方向成分が各導光板の厚み幅で制限された狭い光路内を全反射しながら光路変更素子4側に向けてそれぞれ伝送されるが、垂直方向成分は各導光板内で垂直方向に光路変化を受けながら伝送され、各導光板を通過した分割レーザビームは垂直方向に対してそれぞれ異なった高さに分散した状態で出射することになるので、この分散を少なくして各分割レーザビームが垂直方向でオーバーラップしない程度に接近するように、並設する各導光板の前記変位角度を予め設定し、光路変更素子4の各導光板

に適合する所定幅の平行ビームで出射されるようにしている。

【0027】光路分割素子3の各導光板3-1, 3-2, 3-3を通過した分割レーザービームは、その後段に配置された光路変更素子4にそれぞれ入射されるが、この光路変更素子4は前段の光路分割素子3と同様に光学ガラスや石英ガラスなどのガラスプレート或いは板状に加工した光学結晶などで形成された複数枚(図1では3枚)の方形状をした導光板4-1, 4-2, 4-3を並設状に配置したものであり、光路分割素子3の各導光板とは90°回転した状態で即ち分割レーザービームに対応すべく水平方向に延在する各導光板4-1, 4-2, 4-3を垂直方向に沿って並設し、且つ各導光板の入射側端面に対する分割レーザービームの入射角度がそれぞれ異なるように水平面上において扇形状に順次角度を変位させた状態で並設されている。

【0028】従って、光路分割素子3の垂直な各導光板3-1, 3-2, 3-3を通過した分割レーザービームは、光路変更素子4の水平な各導光板4-1, 4-2, 4-3にそれぞれ入射され、当該光路変更素子4の各導光板内で水平方向に光路変化を受けながら伝送されるが、光路変更素子4の後段に設けた集光素子5による集光を容易にするために、各導光板を通過した分割レーザービームが出射側端面において水平方向でオーバーラップするように、並設する各導光板の変位角度が予め設定されている。

【0029】尚、光路変更素子4の各導光板内における垂直方向成分の広がり角は一般に小さく($<0.5^\circ$)で、導光板の上下両面にレーザービームが当たる量は非常に少ないので、光路変更素子3の場合のように各導光板間に空気層を設けたり、金属膜や誘電体膜等のコーティングを導光板面に施して全反射させる必要性は必ずしもないので、省略することもできる。

【0030】光路変更素子4の各導光板を通過したレーザービームは、その後段に設けた集光素子5に向けて出射されるが、この集光素子5は例えばシリンドリカルレンズ5aと非球面レンズ5bを有し、シリンドリカルレンズ5aで光路変更素子4からの出射光を一旦平行にした後に、非球面レンズ5bによって水平方向成分及び垂直方向成分がそれぞれ絞込まれて焦点Fに集光され、その際における水平方向成分と垂直方向成分の焦点F位置は、前記シリンドリカルレンズ5aによってずれが生じないように予め補正される。

【0031】前記集光素子5に対する水平方向成分の実質的な入射ビーム径は分割数(即ち導光板の数)に逆比例して短くなっているため、集光素子5で集光したときの水平方向のビーム径を入射ビーム径が小さくなった比率で小さくすることができ、またレーザービームの垂直方向成分に対しては、複数の分割レーザービームが垂直方向に並んだ状態で実質的な出射ビーム径は長くなり、集光

素子5で集光したときの垂直方向の集光性は多少損なわれるが、元々広がり角が小さくて平行光に近いので、分割数(即ち導光板の数)を適切な値以下に設定しておけば水平方向成分のビーム径より大きくなることはなく、実用上では問題にならない。

【0032】例えば半導体レーザー1の発光面が10mm(水平) \times 1 μ m(垂直)の場合、垂直方向成分に対するコリメートで0.5°程度の平行度(これは市販のコリメート素子を用いても十分に可能な値である。)にすると、光路分割素子3による水平方向成分の分割数が20分割(導光板を20枚並設する)程度までは垂直方向成分のビーム径が実用上問題になることはない。

【0033】これを、光路分割素子3及び光路変更素子4として3枚の導光板をそれぞれ用いた図1の実施形態に適合させて具体的に述べると、水平方向成分については導光板4-1, 4-3から出射した分割レーザービームが導光板4-2の分割レーザービームと重なり、集光素子5側からみた水平方向のビーム径は導光板4-2の幅とほぼ等しく、半導体レーザー1の水平方向における発光面の幅の約1/3になるので、集光素子5によってレーザースポットの水平方向のビーム径を当初の約1/3に集光させることができる。

【0034】また、光路分割素子3の各導光板から出射される垂直方向のビーム径は、半導体レーザー1から出射された直後にコリメートした径の約3倍となるが、水平方向成分に比べると元の平行度が一般に50倍以上も良いので、光路分割素子3によって垂直方向成分の集光性が多少損なわれても実質的に問題とならない。

【0035】以上に説明した第1の実施形態では、レーザービームの水平方向成分を分割して伝送する光路分割素子3と、この分割レーザービームの水平方向成分を重ね合わせる光路変更素子4を用い、この第1及び光路変更素子3, 4は入射角が異なるように扇状にずらした状態で並設した複数の方形状をした導光板で構成したが、各導光板への入射角は同じにして各導光板からの出射位置が異なるように長さを変えたり、各導光板の屈折率を変えて屈折角が異なるようにし、第1の実施形態と同様に機能させる他の実施形態もある。

【0036】例えば、図2では光路分割素子及び光路変更素子の各導光板へのビーム入射角を等しくして各導光板からの出射位置が異なるように長さを変え、第1の実施形態と同様に機能させた第2の実施形態の基本構成を、(a)は平面図で(b)は正面図でそれぞれ示し、この実施形態では第1の実施形態の場合と同様の半導体レーザー1と、コリメート素子2と、集光素子5とが使用されると共に、光路分割素子3に代わる光路分割素子6と、光路変更素子4に代わる光路変更素子7とが使用されるが、共通する半導体レーザー1と、コリメート素子2と、集光素子5については詳細な説明は省略する。

【0037】光路分割素子6は、垂直方向に延在する平

行四辺形状の複数枚（図2では3枚）の各導光板6-1, 6-2, 6-3を、入射側端面及び出射側端面が垂直面上において入射側に傾斜する態様で水平方向に沿って並設し、且つ各導光板の入射側端面に対するレーザービームの入射角度がそれぞれ等しくなるように入射側端面を整列状態にすると共に、出射位置が順次異なるように各導光板6-1, 6-2, 6-3の長さを変えて出射側端面が階段状になる状態で並設されている。

【0038】これにより、光路分割素子6の各導光板6-1, 6-2, 6-3に入射された分割レーザービームは、水平方向成分は各導光板の厚み幅で制限された狭い光路内を全反射しながら光路変更素子7側に向けてそれぞれ伝送されるが、垂直方向成分は各導光板内で垂直方向に光路変化を受けながら伝送され、各導光板を通過した分割レーザービームは垂直方向に対してそれぞれ異なった高さで出射することになるので、この分散を少なくして各分割レーザービームが出射側端面において垂直方向でオーバーラップしない程度に接近するように、並設する各導光板の長さを入射側端面及び出射側端面の前記傾斜角度を予め設定し、光路変更素子7の各導光板に適合する所定幅の平行ビームとして出射されるようにしている。

【0039】光路変更素子7は、光路分割素子6の各導光板とは90°回転した状態で即ち水平方向に延在する平行四辺形状の各導光板7-1, 7-2, 7-3を、入射側端面及び出射側端面が水平面上において出射側に傾斜する態様で垂直方向に沿って並設し、且つ各導光板の入射側端面に対するレーザービームの入射角度がそれぞれ等しくなるように入射側端面を整列状態にすると共に、出射位置が順次異なるように各導光板7-1, 7-2, 7-3の長さを変えて出射側端面が階段状になる状態で並設されている。

【0040】これにより、光路分割素子6の各導光板を通過して光路変更素子7の各導光板7-1, 7-2, 7-3にそれぞれ入射された分割レーザービームは、当該光路変更素子7の各導光板内で水平方向に光路変化を受けながら伝送されるが、光路変更素子7の後段に設けた集光素子5による集光を容易にするために、各導光板を通過した分割レーザービームが出射側端面において水平方向でオーバーラップするように、並設する各導光板の傾斜角度及び長さが予め設定されている。

【0041】更に、図4では光路分割素子及び光路変更素子の各導光板の屈折率を変えて屈折角が異なるようにし、第1の実施形態と同様に機能させる第3の実施形態の基本構成を、(a)は平面図で(b)は正面図でそれぞれ示し、この実施形態では第1の実施形態の場合と同様の半導体レーザー1と、コリメート素子2と、集光素子5とが使用されると共に、光路分割素子3に代わる光路分割素子8と、光路変更素子4に代わる光路変更素子9とが使用されるが、共通する半導体レーザー1と、コリメート素子2と、集光素子5に付いては詳細な説明は省略

する。

【0042】光路分割素子8は、垂直方向に延在する方形状で屈折率がそれぞれ異なる複数枚（図2では3枚）の各導光板8-1, 8-2, 8-3を、入射側端面及び出射側端面が垂直面上において入射側から見て仰角状に所定角度（例えば45°）に傾斜する態様で水平方向に沿って並設し、且つ各導光板の入射側端面に対するレーザービームの入射角度がそれぞれ等しくなるように入射側端面を整列状態にして並設されると共に、各導光板6-1, 6-2, 6-3は屈折角が異なるように屈折率を変えたものを使用される。

【0043】これにより、光路分割素子8の各導光板8-1, 8-2, 8-3に入射された分割レーザービームは、水平方向成分は各導光板の厚み幅で制限された狭い光路内を全反射しながら光路変更素子9側に向けてそれぞれ伝送されるが、垂直方向成分は各導光板の屈折率に対応する屈折角度で垂直方向に光路変化を受けながら伝送され、各導光板を通過した分割レーザービームは垂直方向に対してそれぞれ異なった高さに分散した状態で出射することになるので、この分散を少なくして各分割レーザービームが垂直方向でオーバーラップしない程度に接近するように、並設する各導光板の屈折率が予め設定（例えば、図3では導光板8-1の屈折率が最も小さくて、導光板8-3の屈折率を最も大きい）されている。

【0044】光路変更素子9は、光路分割素子8の各導光板と同様の構成による各導光板9-1, 9-2, 9-3を、90°転移させた水平状態で使用するものであり、光路分割素子8の各導光板を通過した垂直方向に高さの異なる分割レーザービームが各導光板9-1, 9-2, 9-3にそれぞれ入射されると、この分割レーザービームの水平方向成分は各導光板の屈折率に対応する屈折角度で水平方向に光路変化を受けながら伝送されるが、光路変更素子9の後段に設けた集光素子5による集光を容易にするために、各導光板を通過した分割レーザービームが出射側端面において水平方向でオーバーラップするように、各導光板の屈折率が予め設定（例えば、図3では導光板9-1の屈折率が最も小さくて、導光板9-3の屈折率を最も大きい）されている。

【0045】以上に述べた第1～3の実施形態では、レーザー発光源である半導体レーザー1の発光面から出射されたレーザービームに対し、コリメート素子2でビームの垂直方向（短手方向）成分を平行化した後に、並設した複数の導光板を備えた光路分割素子3, 6, 8にビームの水平方向（長手方向）成分を分割した状態で入射させ、光路分割素子3, 6, 8の各導光板内を伝送させた分割ビームを出射側端面で垂直方向（短手方向）成分がオーバーラップしない程度に集光させ、この分割レーザービームの水平方向成分を並設した複数の導光板を備えた光路変更素子4, 7, 9で重ね合わせた状態にして集光素子5で集光させている。

【0046】

【実施例】図4は、第1の実施形態によるビームの補正方法を具現化した装置を示し、発光源となる半導体レーザ11はSDL社の20WCW半導体レーザ（形SDL-3470-S）を用いているが、この半導体レーザは発光長が水平方向10mmで垂直方向1μmであると共に、発光の広がり角は水平方向15°で垂直方向50°とし、発光波長は810nmである。

【0047】半導体レーザ11から出射したレーザビームは、まず垂直方向成分に対してグラディエントシリン
10 ドリカルレンズ（Doric Lenses Inc 社、USA、ロッド径1mmφ）をコリメート手段12に用いて平行にコリメートすると、垂直方向のビーム径が0.5mmで広がり角は0.4°となり、このあと焦点距離60mm（外径40mmφ）の凸レンズ2個をリレー
13に用いて、テレセントリック光学系となるようにして、コリメートされたビーム径（10mm×0.5mm）を2倍の20mm×1mmに拡大し、光学原理上での広がり角を1/2即ち7.5°×0.2°になるようにした。

【0048】なお、前記リレーレンズ13を用いてビーム径を拡大させると、その後段に使用する光路分割素子14及び光路変更素子15の分割数（導光板の枚数）を一定にした場合における1板当たりの導光板の厚みを厚み
20 することができるので、当該導光板の加工を含む製作が容易になる利点があり、従ってリレーレンズ13は製作上では使用することが望ましいが原理的には必須要件ではない。

【0049】次に、入射端面を2倍に拡大したビーム位置には水平方向成分を分割する光路分割素子14を配置
30 するが、この光路変更素子14には導光板として大きさ50mm×50mmで厚さ2.3mmの石英プレートを9枚重ねた状態で使用され、各導光板16-1～16-9は入射ビームの導光板端面への入射角をそれぞれ変えるために、図で示すように垂直面上で扇状に変位させた状態で並設しているが、変位角度は出射ビームが垂直方向にそれぞれ2.3mmずつずれるように設定した。

【0050】変位角度を2.3mmに設定した理由は、分割した水平方向成分を重ね合わせる光路変更素子15を、光路分割素子14と同じ形状にして製作コストの低減を図るためであり、仮に光路分割素子14の各導光板の厚みを2mmとすると、ずれも2mmになるように光路変更素子14の変位角度を決めれば良いが、光路変更素子15の各導光板の厚みを光路分割素子14からの各ビームの垂直方向成分の径より大きくしないとビームが独立して入射されない
40 のので、そのための余剰寸法を考慮して設定した。

【0051】光路分割素子14の両面には、入射角80°以上のビームに対して全反射する誘電体多層膜のコーティングが施されているが、この誘電体多層膜のコーテ

ィングは導光板内でのビームを全反射するためのものではなく、導光板から出射した後に隣接する導光板に当たる一部のビームを反射させて伝送損失を少なくするための対策であり、また各導光板の両端面（入出射面）には伝送損失を少なくするための対策として反射防止膜を施してあり、更に各導光板の間には導光板内でビームが全反射するよう50μm程度の空気層を設けた状態で並設したが、これらは何れも性能或いは生産性を向上するための手段であって、発明の本質に係わるものではない。

【0052】光路変更素子15は水平方向成分に対して各ビームを重ね合わせるためのものであり、ここでは光路分割素子14と同じ構成のものを並設置を90°変位させた状態で使用しているが、光路変更素子14の場合と違って垂直方向の平行度は非常に良いので、多少の損失を許容すれば必ずしも導光板内でビーム全反射させる必要はなく、従って各導光板間に空気層を設けたり、全反射コートをつけたりしないでそのまま密着状態で並設することも可能であり、また形状も光路分割素子14と同じにする必要もないが、但し各導光板の間隔は光路分割素子14によるビームのずれの間隔と同じにし、且
20 つ水平方向から見てビームが重なるように導光板の角度と厚み及び各導光板の屈折率を調整する必要がある。

【0053】以上の補正光学系によってビームの状態は水平方向からみると出射径が2.3mmで広がり角7.5°のものとなり、また垂直方向から見ると各ビームは光路変更素子15の各導光板より0.2°の角度で出射されるので、近似値には出射径は2.0×7mm（2.3mm×9導光板）で広がり角0.2°のビームとみなすことができ、即ち光学原理によれば出射径と広がり角の積が集光できるスポット径に近似値に逆比例するので、水平方向のビームの集光性はこの補正光学系を使わない場合に比べ約10倍に改善されることになる。

【0054】光路変更素子15の後段には、集光素子16としてシリンドリカル凸レンズ16aと非球面レンズ16bを配置して集光させているが、シリンドリカルレンズ16aは焦点距離が200mmで大きさ30×30mmとし、レンズ16bは焦点距離が50mm（集光時の開口数は水平方向で約0.29、垂直方向で約0.24）として、特にシリンドリカル凸レンズ16aは水平及び垂直両方向の最小スポット位置を光軸上で一致させるために使用している。

【0055】集光素子16で集光した最小スポット位置におけるビームスポットの径は、ビームプロファイラを用いて測定した結果では500μm（水平）×400μm（垂直）となり、固体レーザの励起光に適したビームスポットまで集光でき、而もこれら光学系の透過率は88%ときわめて良好であった。

【0056】また、前記補正光学系を使用した半導体レーザを励起光源17として図5で示す固体レーザを製作

したが、この固体レーザはレーザ媒質18としてNd:YVO₄ (3×3×1mmの形状でNdの濃度は1%のもの)を使用し、一方面(集光レンズ側)には波長1064nmに対して全反射し且つ波長810nmに対しては100%近く透過するコーティングを行うと共に、他方面には波長1064nmに対する反射防止コーティングを行い、レーザ媒質18内に前記の集光方法で得られた波長が810nmでビームスポットが500μm(水平)×400μm(垂直)のレーザビームを励起光19として集光させるようにし、出力ミラー20には反射率95%(透過率5%)で曲率1mの凹面鏡を使用すると共に、レーザ媒質18と出力ミラー20間の共振器長を150mmに設定したものである。

【0057】この固体レーザでは、レーザ媒質18に対する励起光19の入射パワー(励起パワー)を15Wとした時に、出力ミラー20を介して出射された発振光21である波長1064nmの出力パワーは6Wであり、従って光変換効率としては40%と高い変換効率を得られ、前記した従来技術の光ファイバー束を用いた端面励起方法と比べてもさほど遜色無く、而もコスト的にはガラスプレートの導光板を並設した光路分割素子及び光路変更素子は光ファイバー束に比べて遥かに安価である。

【0058】

【発明の効果】以上の説明でも明らかなように、本発明によるレーザビームの補正方法及び装置では、複数の導光板を並設した光路分割素子と光路変更素子を用いて、レーザビームの長手方向成分を一旦分割した状態にした後に集光することによってビーム幅を狭めると共に、元々ビーム幅の狭いレーザビームの短手方向成分に付いては多少の広がりを許容させることで、径の小さい円形状のビームスポットにすることが容易にできる。従って、本発明を例えば固体レーザ用の半導体レーザ励起光源に適用すると、高い光変換効率で励起することが可能で高品質の発振出力ビームが得られる。

【0059】また、その達成には光ファイバー束を用いた従来技術のように高価な手段を必要とせず、光路分割素子及び光路変更素子を構成する導光板にはガラスプレート又は板状に加工した光学結晶を用い、各導光板を所定の配列又は形状と長さ又は屈折率に設定して並設する事によって安価に提供することができる。

【0060】特に、光路分割素子及び光路変更素子の導

光板を第1の実施形態のように構成すると、積層する配列のみを所望に設定すれば同形で同材質のものを量産して使用することができるので、安価に提供することが可能である。

【0061】又、光路分割素子及び光路変更素子の導光板を第2の実施形態のように構成すると、同材質のものを量産して所望の長さに切断して使用することができるので、安価に提供することが可能である。

【0062】更に、光路分割素子及び光路変更素子の導光板を第3の実施形態のように構成すると、屈折率のみを所望に設定すれば同形のものをそのまま積層して使用することができるので、材料コストは前2者に比べて多少高価にはなるが組立てコストが安価になって全体としては安価に提供することが可能である。

【図面の簡単な説明】

【図1】本発明のレーザビームの補正方法及び装置を適用した第1の実施形態による基本構成を、(a)は平面図で(b)は正面図でそれぞれ示す。

【図2】本発明のレーザビームの補正方法及び装置を適用した第2の実施形態による基本構成を、(a)は平面図で(b)は正面図でそれぞれ示す。

【図3】本発明のレーザビームの補正方法及び装置を適用した第3の実施形態による基本構成を、(a)は平面図で(b)は正面図でそれぞれ示す。

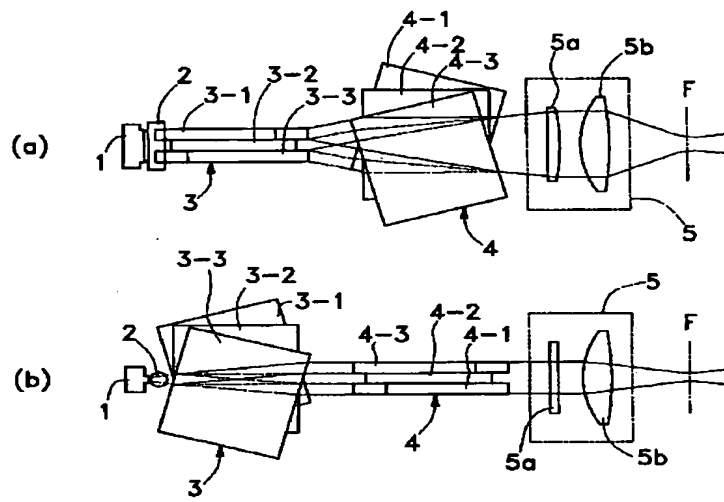
【図4】本発明のレーザビームの補正方法及び装置を適用した第1の実施形態をより具体的に示したものであり(a)は平面図で(b)は正面図でそれぞれ示す。

【図5】図4の装置を励起光源とした固体レーザの説明図である。

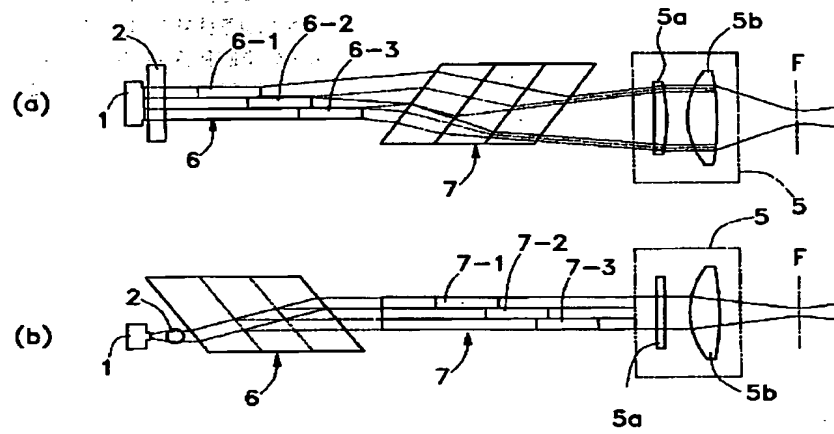
【符号の説明】

- 1, 11 半導体レーザ
- 2, 12 コリメート素子
- 3, 6, 8, 14 光路分割素子
- 4, 7, 9, 15 光路変更素子
- 5, 16 集光素子
- 13 リレーレンズ
- 17 励起光源
- 18 レーザ媒質
- 19 励起光
- 20 出力ミラー
- 21 発振光

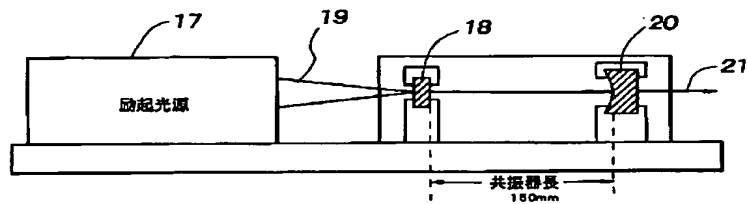
【図1】



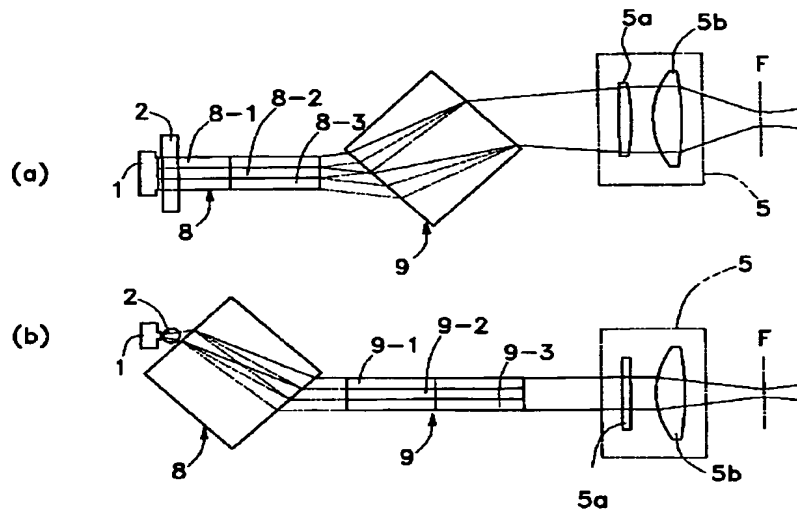
【図2】



【図5】



【図3】



【図4】

